



TITLE:

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A New Striped *Ichthyophis* (Amphibia: Gymnophiona: Ichthyophiidae) from Kon Tum Plateau, Vietnam

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Abstract: A new striped *Ichthyophis* is described on the basis of three specimens collected from Kon Tum Plateau in central Vietnam. The new species is distinguished from all other striped congeners by a combination of characters that includes moderate body size and number of annuli, robust body and tail, broad and uninterrupted lateral stripe, tentacle far from eye, and small number of scale rows. The mitochondrial DNA sequence of the new species greatly differs from those of the other striped *Ichthyophis* from Indochina and its adjacent areas.

Key words: Caecilian; *Ichthyophis*; Taxonomy; New species; Indochina

INTRODUCTION

Vietnam is a major center of amphibian diversity in Indochina (Nguyen et al., 2009). Even in this decade, many new species have been described from that country every year (reviewed by Bain et al., 2007). Many taxonomic studies have been conducted on amphibians living in terrestrial, arboreal, and aquatic habitats, but studies on fossorial caecilians (Gymnophiona) have been very limited, just as in other countries of Southeast Asia (Nishikawa et al., 2012). Their basically secretive life under the ground has prevented collecting them in sufficient numbers for taxonomic studies even in countries like Vietnam, where vigorous herpetological surveys have

been conducted.

Only one ichthyophiid genus, *Ichthyophis* Fitzinger, 1826, has been recorded from Indochina. Species of this genus can be divided into two groups; one with a pair of light cream or yellow lateral stripes, and the other lacking such stripes.

In Vietnam, only one species of striped caecilian, *Ichthyophis bannanicus* Yang, 1984, has been recorded (Nguyen et al., 2009). However, Gower et al. (2002) and Nishikawa et al. (2012) independently examined the molecular phylogeny of Southeast Asian *Ichthyophis* (including *Caudacaecilia* Taylor, 1968) and found two distinct lineages in Indochina. One, from southern China, northern Vietnam, Laos, and northeastern Thailand, was identified as *I. bannanicus*, but another from Kon Tum Plateau, central Vietnam, proved to be an unidentified *Ichthyophis* (Nishikawa et al., 2012). The unidentified specimens share a

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distinct combination of morphological characteristics that distinguish them from all other striped *Ichthyophis*. We, thus, describe the specimens as a new species.

MATERIALS AND METHODS

Field surveys were made in Kon Plong District, Kon Tum Province, central Vietnam. After tissues were taken for genetic analysis, specimens were fixed in 10% formalin, then preserved in 70% ethanol, and stored in the Zoological Institute, Russian Academy of Sciences, St. Petersburg (ZISP), the Graduate School of Human and Environmental Studies, Kyoto University (KUHE), and the Vietnam National Museum of Nature (VNMN).

We measured the following morphometric characters to the nearest 0.1 mm with a dial caliper, based on Kupfer and Müller (2004) and Nishikawa et al. (2008) with a minor modification: total length (TL); head length (HL) from tip of snout to first collar groove, measured dorsally; trunk length (TRL) from first collar groove to posterior end of vent; tail length (TAL) from posterior end of vent to tail tip; vent length (VL); snout length (SL) from tip of snout to jaw angle; lower jaw length (LJL) from tip of lower jaw to jaw angle; snout-2nd collar groove length (S2CL), measured ventrally; snout-3rd collar groove length (S3CL), measured dorsally; 1st collar length (1CL), measured laterally; 2nd collar length (2CL), measured laterally; head width (HW) at jaw angle; maximum head width (MXHW); body width at middle (BWM); tail width at posterior vent (TAW); lateral stripe width at middle (LSWM); interorbital distance (IOD); intertentacle distance (ITD); internarial distance (IND); eye-nostril distance (END); eye-tentacle distance (ETD); tentacle-nostril distance (TND); and eye-jaw angle distance (EJD).

We also counted the following meristic characters: total annuli (TA); annuli interrupted by vent (VA); post-vent annuli (PVA); dorsal transverse grooves on 2nd collar (DTG); premaxillary-maxillary teeth (PMM); vomeropalatine teeth (VP); dentary teeth (DE); sple-

nial teeth (SP); and vertebrae (VER). The number of vertebrae was counted from a soft X-ray photograph using Fuji Medical X-Ray Film (RX-U).

SYSTEMATICS

Ichthyophis nguyenorum sp. nov. (Figs. 1–3)

Ichthyophis sp.: Gower et al., 2002, p. 1566.

Ichthyophis bannanicus: Nguyen et al., 2009, p. 191–192 (part).

Ichthyophis sp. 2: Nishikawa et al., 2012, p. 717.

Diagnosis

Ichthyophis with broad and uninterrupted lateral stripes extending from near eye and tentacle to the posterior end of vent; body uniformly slate above, lilac below. Total lengths of three adult females 256.5–306.5 mm; TL/BWM ratio 21.7–24.9; tail shorter (2.5–3.1 mm) than wide (3.4–4.3 mm); annuli 312–318 of which four in tail; 27–37 premaxillary-maxillopalatine, 23–28 vomeropalatine, 24–28 dentary, 21–25 splenial teeth. TND/ETD ratio 1.6–1.8. Scales from anteriormost 10th to 15th annuli to end of body, number of rows increasing in posterior annuli up to four.

Holotype

ZISP 10711 (field number ZISP 39430), an adult female (Figs. 1–3) from Mang Canh Village, Kon Plong District, Kon Tum Province, Vietnam (14°41'18" N, 108°19'28" E, 1200 m asl), collected by Nikolai L. Orlov on 20 April 2006.

Paratypes

Two adult females: KUHE 55007 (field number ZISP 39442) collected by Nikolai Orlov on 18 April 2006 and VNMN 3481 (field number ZISP 39982) collected by Nikolai L. Orlov on 22 April 2006 at same locality as the holotype. The GenBank accession numbers of sequences of KUHE 55007 are AB686104 (cytochrome b) and AB686169 (12S-16S rRNA).

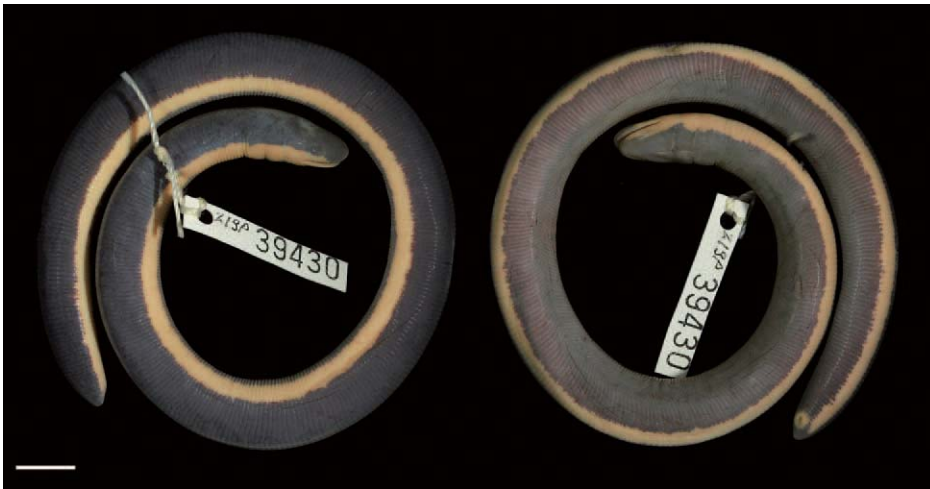


FIG. 1. Holotype of *Ichthyophis nguyenorum* sp. nov. (ZISP 10711) in dorsal (left) and ventral (right) views. The tag attached shows the ZISP field number. Scale=10 mm.

Description of holotype (measurements in mm)

Moderate sized (TL 306.5); body subcylindrical, slightly depressed dorsoventrally, tapering posteriorly, more abruptly at about one fifth of body, ending in blunt tail tip, lacking nipple-like terminal cap; head widened slightly around jaw angle and narrowing anteriorly; snout rounded anterior to tentacles, slightly longer (8.9) than lower jaw (8.4); intertentacle distance (6.5) larger than interorbital distance (5.6), in turn much larger than internarial distance (2.5); eye slightly protruded, almost midway between top of head and edge of mouth in lateral view, slightly inset from edge of head in dorsal view; tentacle less than twice as far from nostril than eye ($TND/ETD=1.8$); eye-jaw angle distance (3.2) larger than eye-tentacle distance (2.0), but slightly smaller than tentacle-nostril distance (3.5); tentacle very close to edge of mouth, long and thin in life, tip slightly protruding from tentacular sheath in preservative; second collar (4.4) longer than first collar (3.3); nostril positioned closely at anterior margin of mouth in dorsal and lateral views.

Collar region slightly wider than head and anterior body in dorsal and ventral views, not higher than head and anterior body in lateral

view; first collar groove evident as constriction separating head and trunk, curving slightly anteriorly towards dorsal midline, where groove becoming incomplete and tips separated; second collar groove evident ventrally but not apparent dorsally, parallel to first groove laterally, fading out near upper margin of lateral stripe; third collar groove not clearly differentiated from anteriormost annular grooves of trunk and dorsal transverse grooves on second collar, but recognized as first groove crossing lateral to ventral body; third groove dorsally complete, curving slightly anteriorly towards dorsal midline, but tips separated midventrally; two dorsal transverse grooves on second collar.

Annular count 318; annular grooves complete dorsally, but narrowly separate ventrally except for posterior one tenth of body; dorsally, annular grooves curving slightly anteriorly towards midline on anterior one-fourth of body and nearly orthoplicate on posterior three-fourths of body; ventrally, grooves strongly angulate posteriorly towards midline, degree of curvature decreasing posteriorly to becoming orthoplicate at ca. one-tenth of body. Scales found on posterior nine-tenths of body, number of rows tending to increase in posterior annuli up to three.

Longitudinal vent surrounded by small and whitish subcircular disc; six denticulations on each side of vent and one small denticulation on posterior end; no papillae on disc; four annuli each in vent slit including denticulations, and in tail.



FIG. 2. Holotype of *Ichthyophis nguyenorum* sp. nov. (ZISP 10711). From top to bottom: head and anterior body in dorsal, ventral, and lateral views; posterior body in dorsal, ventral and lateral views. Scale=10 mm.

Teeth on premaxillary-maxillopalatine 17/19 (left/right), vomeropalatine 14/12, dentary 13/13, splenial 13/12. Choanae elongated, about three times as long as broad, obliquely extending posterolaterally.

Color

In life, ground color of dorsum uniform slate; paler, lilac ventrally (Fig. 3); lateral stripe bright yellow, broad, and uninterrupted throughout the body, extending from just behind tentacle on upper jaw and anterior one fourth on lower jaw to posterior end of vent disc; anterior end of stripe forming forks on lower jaw; eye surrounded by narrow whitish ring; tentacle and surrounding tentacle aperture whitish; vent disc whitish. In preservative, color and pattern faded but not obviously changed (Figs. 1–2).

Variation

Individuals of the type series are generally similar in morphology (Table 1). The holotype (TL=306.5 mm) is larger than the two paratypes (256.5–267.0 mm). However, the width of lateral stripe (LSWM) is nearly uniform among members of the type series (3.4–3.5 mm). Paratypes have slightly smaller number of total annuli (312 and 313) than the holotype. One paratype (VNMN 3481) has smaller number of teeth (PMM, VP, DE, and SP) than the others. The type specimens are also similar in color and pattern. One paratype



FIG. 3. Holotype of *Ichthyophis nguyenorum* sp. nov. (ZISP 10711) in life.

IOD	5.6	5.6	5.8	6.5	7.7	7.6	6.9	5.6	5.3	5.3	4.9	5.2	5.9	4.6	4.9
ITD	6.5	5.8	5.7	7.3	8.4	8.1	7.0	—	5.5	5.1	4.9	5.4	—	—	4.8
IND	2.5	2.6	2.3	2.8	3.3	3.3	3.1	2.8	1.4	2.3	2.1	2.1	2.7	2.5	2.3
END	4.7	4.4	4.5	4.9	5.7	5.5	5.1	3.7	3.9	3.8	3.6	4.0	4.7	3.2	4.1
ETD	2.0	2.1	2.0	2.0	2.5	2.2	2.2	1.4	1.7	1.5	1.5	1.7	1.8	1.4	1.9
TND	3.5	3.4	3.1	3.7	4.4	4.0	3.6	3.2	3.1	3.1	2.7	3.1	3.0	2.3	2.8
EJD	3.2	3.1	3.2	3.3	4.1	3.8	3.4	—	2.7	2.4	2.1	2.6	—	—	2.7
Meristic															
TA	318	313	312	364	383	345	373	358	296	286	294	302	321	303	294
VA	4	4	4	4	4	4	3	—	4	4	3	4	—	—	4
PVA	4	3	3	6	5	4	4	—	3	3	4	4	—	—	5
DTG	2	3	3	2	2	1/2	2	3/4	0	1	1	1	1/2	2	1
PMM	17/19	19/18	14/13	24/23	21/20	20/22	19/18	21/22	17/20	19/19	15/17	22/25	31/23*	18/18	15/15
VP	14/12	14/14	12/11	19/22	19/20	19/18	16/16	19/20	19/19	18/16	17/17	20/20	26/25	18/17	15/17
DE	13/13	15/13	11/13	20/16	17/16	20/17	18/17	20/20	18/19	16/18	14/15	18/18	8*/4*	18/15	14/14
SP	13/12	12/13	10/11	13/13	13/12	15/16	13/11	9/14	9/8	10/10	7/6	9/8	2*/9*	8/10	8/9
VER	121	117	114	112	114	111	114	119	112	115	122	112	112	115	121
Ratio															
TL/BWM	24.9	21.7	24.0	28.5	25.9	24.8	30.4	27.5	30.2	29.2	29.2	30.7	31.6	27.6	24.8
TND/ETD	1.8	1.6	1.6	1.9	1.8	1.8	1.6	2.3	1.8	2.1	1.8	1.8	1.7	1.6	1.5

(VNMN 3481) has a cream yellowish spot at the tail end.

Egg and larva

Ovary of one female (VNMN 3481) contains ova of varying size with the maximum of 3.5 mm in diameter. Larva unknown.

Comparisons

Ichthyophis nguyenorum differs from other striped *Ichthyophis* from Indochina in the following way: from *I. bannanicus* by having smaller number of total annuli (312–318) and complete lateral stripe (total annuli more than 340, and lateral stripe broken especially posteriorly in *I. bannanicus*), and from *I. kohtaoensis* Taylor, 1960 and *I. supachaii* Taylor, 1960 by having more robust body (TL/BWM < 25) and wider lateral stripe (> 3.4 mm) (body slender [TL/BWM mostly > 25] and lateral stripe narrow [< 2.3 mm] in *I. kohtaoensis* and *I. supachaii*).

The new species differs from other striped congeners as follows (data from Taylor, 1968; Pillai and Ravichandran, 1999; Wilkinson et al., 2007; Kamei et al., 2009; Mathew and Sen, 2010); *Caudacaecilia* Taylor, 1968 recently synonymized with *Ichthyophis* (Nishikawa et al., 2012) excluded: from *I. alfredi* Mathew and Sen, 2009 by having larger number of annuli (312–318), smaller number of post-vent annuli (3–4), and thick, blunt tail (vs. less than 300 annuli, 5–7 post-vent annuli, and narrow and pointed tail in *I. alfredi*); from *I. atricollaris* Taylor, 1965 by having complete lateral stripe in collars and having larger number of total annuli and splenial teeth (312–318 and 10–13) (vs. having interrupted lateral stripes, 263–310 total annuli and 5–8 splenial teeth in *I. atricollaris*); from *I. beddomei* Peters, 1880 by having tentacle close to eye (TND/ETD > 1.6) and smaller number of splenial teeth (21–25) (vs. tentacle far from eye [TND/ETD < 1.3] and 35–44 splenial teeth in *I. beddomei*); from *I. bernisi* Salvador, 1975, *I. elongatus* Taylor, 1965, *I. hypocyaneus* (Boie, 1827), *I. paucisulcus* Taylor, 1960, and *I. pseudangularis* Taylor, 1965 by having tentacle less than

twice as close to eye than to nostril (TND/ETD < 2.0) (vs. tentacle nearly or more than twice as close to eye than to nostril [TND/ETD > 2.0] in *I. bernisi*, *I. elongatus*, *I. hypocyaneus*, *I. paucisulcus*, and *I. pseudangularis*); from *I. biangularis* Taylor, 1965 by having complete lateral stripes in collars and having larger numbers of splenial teeth (10–13) (vs. having complete lateral stripes and four splenial teeth in *I. biangularis*); from *I. daribokensis* Mathew and Sen, 2009 by having smaller number of post-vent annuli (3–4), and thick, blunt tail (vs. 4–7 post-vent annuli, and narrow and pointed tail in *I. daribokensis*); from *I. garioensis* Pillai and Ravichandran, 1999 by having larger body (> 256 mm) and larger number of annuli (> 312), smaller number of splenial teeth (10–13), and thick, blunt tail (vs. body length smaller than 220 mm, annuli less than 290, 14–15 splenial teeth, and tail narrow and pointed in *I. garioensis*); from *I. glutinosus* (Linnaeus, 1758) by having smaller number of total annuli (< 320) (vs. more than 340 annuli in *I. glutinosus*); from *I. kodaguensis* Wilkinson, Gower, Govindappa, and Venkatachaliah, 2007 by having larger number of total annuli (> 312) and smaller number of scale rows (up to three) (vs. less than 310 annuli and up to six scale rows in *I. kodaguensis*); from *I. khumhzi* Kamei, Wilkinson, Gower, and Biju, 2009, *I. moustakius* Kamei, Wilkinson, Gower, and Biju, 2009, and *I. sendenyu* Kamei, Wilkinson, Gower, and Biju, 2009 by lacking moustache-like stripes between tentacles and nostrils (vs. having a distinctive moustache-like stripes in *I. khumhzi*, *I. moustakius*, and *I. sendenyu*); from *I. longicephalus* Pillai, 1986 by having larger body (> 256 mm) and smaller number of total annuli (< 320) (vs. body smaller than 200 mm and nearly 350 total annuli in *I. longicephalus*); from *I. nokrekensis* Mathew and Sen, 2009 by having normal head and smaller number of post-vent annuli (3–4) (vs. head dorsally concave and 5–7 post-vent annuli in *I. nokrekensis*); from *I. tricolor* Annandale, 1909 by lacking midventral stripe (vs. with a



FIG. 4. Type locality of *Ichthyophis nguyenorum* sp. nov.

whitish midventral stripe in *I. tricolor*).

Range

Known only from the type locality and its vicinity (Te Xang, see discussion below) in Kon Tum Province, Vietnam.

Natural history

Type specimens were collected on the forest floor after heavy rain between 1900 and 2400 h. The habitat at the type locality is a secondary forest near a farmland (Fig. 4). Information about breeding, hatching, larval period, and metamorphosis is lacking.

Etymology

The species name is dedicated to Vietnamese brother herpetologists, Nguyen Quang Truong and Nguyen Thien Tao. They have contributed greatly to elucidating herpetofaunal diversity in Vietnam by vigorous surveys.

DISCUSSION

The taxonomy of Southeast Asian *Ichthyophis* has been left unrevised since Taylor's work in the 1960s (Taylor, 1960, 1968). Because of difficulty in collection and identification of specimens, few researchers conducted taxonomic study of this group. It is obvious that the species diversity of caecilians is underestimated as shown by several unidentified, probably new, species reported by Nishikawa et al. (2012).

Ichthyophis nguyenorum was first reported as *Ichthyophis* sp. (Gower et al., 2002) from Te Xang (formerly Mang Xang), Kon Tum Province, close to the type locality (Nishikawa et al., 2012). These localities are in the Kon Tum Plateau, which is a part of the Central Highlands of Vietnam, with the highest peak Mt. Ngoc Linh (2598 m asl). Until now, *I. nguyenorum* was known only from this plateau. During this decade, several new amphibian species endemic to the plateau have been described (e.g., Orlov, 2005, 2009; Orlov et al., 2006; Rowley and Cao, 2009). The present discovery of *I. nguyenorum* suggests that amphibian species diversity has still been not sufficiently elucidated in the area.

The occurrence of *I. bannanicus* (type locality, Yunnan, China) in Vietnam has been reported throughout its area (Nguyen et al., 2009). The northern populations have been studied molecularly and identified as *I. bannanicus* because of small sequence divergence from the specimens from near the type locality (Gower et al., 2002). The Vietnamese populations of *I. bannanicus* may occur sympatrically with *I. nguyenorum*. In order to understand the pattern of distribution in *I. nguyenorum* and *I. bannanicus*, it is necessary to examine more specimens not only from Vietnam, but also from adjacent Laos and Cambodia. Furthermore, adult male and larval specimens of *I. nguyenorum* are also needed for a more complete characterization of this species, now known from only three females.

Phylogenetic position of *I. nguyenorum* among species from Indochina and its adjacent areas was assessed by Nishikawa et al. (2012) based on mitochondrial sequences, as *Ichthyophis* sp. 2 using a tissue of the paratype: KUHE 55007 (the ZISP field number ZISP 39442 [shown as "ZISP 39442 or 39334" in Table 1 of the paper]). They showed that the uncorrected p-distances between *I. nguyenorum* and *I. bannanicus* (mean = 13.4% in cytochrome b and 5.9% in 12S-16S rRNA genes) were much larger than smaller ones between branches recognized as

heterospecific groups in their study (7.2% in cytochrome b and 2.8% in 12S-16S rRNA). This result strengthened the heterospecific status of *I. guyenorum* and *I. bannanicus*.

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